

Superstrings and the Euler-Kant Mirror:

Deconstructing Kant's Debut

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1. A Misleading Stereotype?

Tom Rockmore stated, “Most writers on Immanuel Kant are properly concerned with the works of his mature, or critical period in which he worked out the critical philosophy ... for which he is justly renowned as one of the very small handful of really great philosophers.”¹ This is a carefully worded reflection on the scholarly consensus. The beginning of modern philosophy (in contradistinction to early modern thought) is often dated at 1781, when Kant published the *Critique of Pure Reason*. As L. W. Beck put it, prior to the critical period Kant “would deserve a quarter of a page in Überweg”—which is not a

¹ T. Rockmore, “Introduction,” *New Essays on the Precritical Kant* (Amherst: Humanity 2001), 7.

compliment, for the “Überweg” has five volumes.² The precritical Kant has mostly been dismissed. He is usually characterized as an eclectic writer, steeped in Leibnizian-Wolffian metaphysics, with an oeuvre both incoherent and erratic, who worked on issues now obsolete, and who had not yet woken from his dogmatic slumber.³

The problem with this verdict is that it raises more questions than it can answer. Since Kant’s philosophical career spanned half a century, from 1745 to 1801, the verdict suggests that the late and critical Kant was “really great”, or, even more pointedly, “mature,” whereas the early and precritical Kant was neither. He wrote his Inaugural Dissertation (1770), which straddles the periods, when he turned forty-six. Does this mean he was immature until reaching middle age? Is it plausible to assume that one and the same thinker, who started writing when twenty, remains mediocre for almost three decades and then, suddenly, blooms into a genius—when growing old?

Granted, Kant’s early efforts were mainly in philosophy of nature and thus metaphysics. But is metaphysics always mediocre, even if the conjectural predictions of a synthetic narrative repeatedly anticipate scientific discoveries? Is metaphysics as “meaningless” as Anglophone thinkers might say when its conceptual aperçus solve empirical puzzles of climate science, such as why some winds blow in patterns, or

²² L. W. Beck, *Early German Philosophy: Kant and his Predecessors* (Cambridge: Harvard 1969), 429. Friedrich Überweg’s *Grundriß der Geschichte der Philosophie* appeared in 2 volumes 1862-64, grew to 4 volumes in the 8th edition 1897, and to 5 volumes in the 12th edition (Berlin: Mittler 1924), which is the edition Beck refers to; cf. *ibid.* 506.

³ For the charge of eclecticism and lack of originality, see Beck, *loc. cit.*, 426-30; for the charge of erratic turns and incoherence, see Ernst Cassirer, *Kant’s Life and Thought* (orig. 1918), trans. J. Haden (New Haven: Yale 1981), 92-4.

why the monsoon happens in a season?⁴ Kant's early speculations were certainly bold, and sometimes outrageously so—as on free field radiation, the fate of Earth's rotation, the formation of solar systems, or on the dynamic structure of galaxies. But has not each of them, in the meantime, entered the standard model of physics?⁵

One might argue with Kant's perhaps boldest precritical contention that nature is developing toward ever more complex and ultimately reflective states of self-organization.⁶ We could point to the second law of thermodynamics and its prohibitions. But is it not the case that Kant's radical conjecture, applied to the known history of the cosmos, has been well confirmed?

⁴ Kant explains coastal winds in *Universal Natural History* (1755) and *Theory of Winds* (1756); see Academy Edition 1:223-4 and 1:492-4; in *Theory of Winds*, he also explains trade winds (1:494-6), equatorial passat winds (1:496-8), and the monsoon (1:499-500). Compare Martin Schönfeld, *The Philosophy of the Young Kant* (New York: Oxford 2000), 73-84, 262.

⁵ Compare the appraisal of Kant's discoveries by John D. Barrow, *The Universe that Discovered Itself*, revised edition (Oxford, UK: Oxford 2000), 84-93, 105, 209-10. See also the assessment of Kant's cosmology by Peter Coles, in Coles, ed., *Routledge Companion to the New Cosmology* (London: Routledge 2001), 240-41, as "the essence of modern models".

⁶ See Kant, *Universal Natural History*, preface, ii.1, ii.7, and iii (1:224-34, 263-4, 311-18, 354-7).

And has thermodynamics not been shown to be less “entropic” than it was originally assumed?⁷

Today, claims often scoffed at by scholars (and that would prompt them to dismiss Kant’s precritical project) have advanced to science, either as settled standards or as current inquiries. And as science substantiates Kant’s early conjectures, so it undermines the dismissal of the precritical philosophy in the humanities. Apparently these ideas have potential. If this is true, then the irony of Kant scholarship will be that it underestimated its subject matter. Perhaps, then, the precritical metaphysics needs to be studied again, with care, and less *critically* than before.

⁷ See G. Dewel, D. Kondepudi, I. Prigogine, “Chemistry Far from Equilibrium: Thermodynamics, Order and Chaos,” 440-64, in Nina Hall, ed., *The New Chemistry* (Cambridge UK: Cambridge 2000), esp. 440: “The results obtained in non-equilibrium physics and chemistry shed new light on properties of matter ... Far-from-equilibrium matter acquires new properties, leading to new forms of coherence exemplified by chemical waves and chemical clocks ... In many ... popular texts, it is claimed that irreversibility, as those factors associated with entropy increase, leads only to disorder and to a forgetting of the initial conditions. Self-organization shows that this is not so. It is through irreversible processes that the most delicate structures around us, such as those associated with living systems, came into existence.” Compare C. K. Biebricher, G. Nicolis, P. Schuster, “Self-Organization in the Physico-Chemical and Life Sciences,” Contract Study # PSS 0396, *Report EUR 16546 to the European Commission* (Brussels: DG XII 1995).

2. Puzzles: Knutzen, Bilfinger, and especially Euler

Kant's academic debut comprises the decade from 1747 to 1756. In this period, Kant wrote two books, *Living Forces* (1747) and *Universal Natural History* (1755), and earned his academic degrees, his Master's, doctorate, and professorial degree. His three dissertations are *On Fire* (M.A. 1755), *New Elucidation* (doctor 1755), and *Physical Monadology* (professor 1756).⁸ A reappraisal of Kant's debut could take its cue from its boundaries, its first and last texts of this period; his ill-fated first book, *Thoughts on the True Estimation of Living Forces*, written in 1747 and printed in 1749, and his professorial thesis, *The Use of Joining Metaphysics and Geometry in Natural Philosophy, whose First Example is Physical Monadology*, publicly defended in 1756.

The context of Kant's debut involves several puzzles. Three are especially interesting: Kant's relation to his first academic teacher, Martin Knutzen (1713-51), to his first heuristic guide, Georg Bilfinger (1693-1750), and to his first intellectual hero, Leonard Euler (1707-83). Each relation raises a question—Knutzen for religion, Bilfinger for hermeneutics, and Euler for nature.

The puzzle over Knutzen and religion concerns Kant's academic failure. Kant studied at Königsberg from 1740 to 1748. After *Living Forces*, he left without a degree. Kant's first book

⁸ The longer titles of the works are as follows: *Thoughts on the True Estimation of Living Forces*; *Universal Natural History and Theory of the Sky*; *Outline of Some Reflections on Fire*; *New Elucidation of the First Principles of Metaphysical Cognition*; and *The Use of Joining Metaphysics and Geometry in Natural Philosophy, whose first Sample contains the Physical Monadology*. Compare Cambridge Edition, *Theoretical Philosophy 1755-1770*, xxiii-xxiv.

is in German, not in the Latin of an academic thesis. Kuehn (2001a) analyzed Kant's difficulties with Knutzen, his academic advisor.⁹ This may have led to not writing—and not submitting—*Living Forces* as a thesis and may have contributed to the delay of Kant's graduation until 1755, with another thesis, on *Fire*, after Knutzen's death (1751). It seems Kant could not advance as long as Knutzen was in charge. They had philosophical differences, as their conflicting opinions about Leibniz show. The role of religion in their conflict needs study. The teacher was a Pietist, which, as Kuehn (2001b) showed, the student was not.¹⁰ Is this why Knutzen flunked Kant?

The puzzle over Bilfinger and hermeneutics concerns the link—if any—of *Living Forces* to Chinese philosophy, especially Taoist ontology. In § 20-21, Kant adopts his dialectics of synthesis as his permanent (*jederzeit*; 1:32.6) “rule in for investigating truths”. Albrecht (1985) has shown how Wolff consulted Bilfinger when preparing the Confucius-speech at Halle 1721 for publication in exile.¹¹ Bilfinger was a China-expert. He had written on the Classics that had been edited by the Neoconfucian Zhu-Xi, who linked Confucian

⁹ Manfred Kuehn, “Kant's Teachers in the Exact Sciences,” 11-30 in Eric Watkins, ed., *Kant and the Sciences* (New York: Oxford 2001), esp. 19-2

¹⁰ See Manfred Kuehn, *Kant: A Biography* (Cambridge, UK: Cambridge 2001). Examining the first biographies (Borowski, Jachmann, Wasianski, Rink), Kuehn shows that the portrait of Kant as a Christian shaped by Pietism is a distortion, cf. *ibid.* 2-16. For Kant's views on his Pietist education (“in the servitude of fanatics”), see *ibid.* 45-55; for the old Kant's scorn for organized religion, disbelief in an afterlife, and rejection of a monotheistic God, see *ibid.* 328, 369-82, 392.

¹¹ See Michael Albrecht, “Einleitung,” ix-cvi in Christian Wolff, *Oratio de Sinarum philosophia practica*, ed. and trans. M. Albrecht (Hamburg: Meiner 1985), esp. liii-lxx. Interesting is the preface (1726) of Wolff's speech; compare *ibid.* p. 4-6, lines 1-52.

ethics to the Tao through force (*qi*) and form (*li*). Did the *Doctrine of the Mean*, from the “book of rites,” inform Bilfinger’s method for reading force, Bilfinger’s rule of dialectic harmony? We need to know how Bilfinger’s rule, which inspired and guided Kant, was imported from China. We need to know what Kant appropriated from the Tao.

The final puzzle that could be riddled here, and in the deconstruction of Kant’s debut arguably the most vexing of the scholarly problems, concerns Kant’s relation to Euler over nature. There is an as yet unexamined affinity of their insights into sensible and intelligible structures.

Mathematicians know Euler through Euler integrals, Euler numbers, the Euler-MacLaurin summation formula, Euler’s sum of the harmonic series, and the Euler constant. Students learn his symbols for function $f(x)$, for the log base e , for summation Σ , and for the 3.14-circle ratio π . Historians of mathematics know him as “the most prolific writer of mathematics of all time”.¹² Historians of physics know his work on “living force” or kinetic energy, the problem that led Kant to philosophy, and whose solution is Euler’s. Mathematical analysis, analytic mechanics, and fluid dynamics all started with Euler.¹³ Kant scholars know Euler as the only senior recipient of a desk-copy of Kant’s first work, *Living Forces*, and as the inspiration behind Kant’s

¹² J. J. O’Connor and E. F. Robertson, “Leonard Euler,” *MacTutor History of Mathematics Archive* (University of St Andrews, Scotland), URL <http://www-gap.dcs.st-and.ac.uk/>, accessed July 2004.

¹³ For Euler as founder of mathematical analysis and analytic mechanics, see O’Connor and Robertson, loc. cit. For Euler as founder of fluid dynamics, see G. A. Tokaty, *A History and Philosophy of Fluid Dynamics* (orig. pub. 1971; New York: Dover 1994), 70-77. Fluid dynamics is popularly associated with Daniel Bernoulli (1700-82). Euler was his closest friend, roommate, and mentor. Tokaty, *ibid.*, argues that the actual credit goes to the latter, not to the former.

professorial thesis, *Physical Monadology*. He also happens to be the receiver of Kant's very first letter (1749; cf. *Correspondence* 45-6).

The letter is unique. The text is an unconditional homage without equal in Kant's lifework. As a document, the letter is also the earliest known handwriting by Kant. He begs Euler to read his book; he thinks only Euler can heal the rift in the sciences and that confuses the disciplines, and while respecting Euler's towering status, Kant insists he and Euler are on the same page.¹⁴

Without doubt, Kant's debut leads to Euler.

Recently Euler reached a wide audience with popular accounts on the structure of nature. The current revolution in physics began with string theory, led to superstrings and now to

¹⁴ The letter is not in the Academy edition, see Leonard Euler, *Opera Omnia: Series Quarta A, Briefwechsel* (Basel: Birkhäuser 1975) 1:14. For a translation (Arnulf Zweig), see Cambridge edition, *Correspondence* 45-6. Compare Harald-Paul Fischer, "Kant an Euler," *Kant-Studien* 76 (1985): 214-18, and "Eine Antwort auf Kants Briefe vom 23. August 1749," loc. cit.: 79-89. Kant writes: "The same audacity that prompted me to seek out the true quantity of natural force and to pursue the reward of truth . . . prompts me to submit this work to the judgment of a man whose discernment qualifies him better than anyone to carry forward the efforts I have begun in these wretched essays and to reach a final and full resolution of the division among such great scholars. The world sees in you, esteemed sir, the individual who better than others is in a position to rescue the human understanding from its protracted error and perplexity concerning the most intricate points of Mechanics, and it is just this that moves me to solicit most respectfully your precise and gracious appraisal of these poor thoughts . . . If you do me the honor of either publishing or sending me privately your treasured judgment of this modest work, I shall then begin to have a certain respect for it." Trans. A. Zweig, Cambridge edition, *Correspondence* 45-6.

branes (for M-theory, strings are branes seen on edge). Superstrings or M-branes may be the elements of mass. (Just as quantum loops may be the elements of spacetime.) Some physicists celebrate these ideas as leaps to a so-called theory of everything, the dream of the final theory of nature.¹⁵ The superstring revolution started in Switzerland with the study of strong elementary interactions. Its trigger was the physical interpretation of Euler's beta function.¹⁶

This turns the Kantian puzzle over Euler and nature into a vexing philosophical question. If we wonder what to make of Kant's debut today, here's the rub. Do we need to take Kant's debut seriously, in light of its confirmed aperçus, as a conceptual mirror of Euler's advances?

¹⁵ For summaries, see Steven Weinberg (Nobel 1979), *Dreams of a Final Theory: the Search for the Fundamental Laws of Nature* (London: Vintage 1993), c. 9 "The Shape of a Final Theory," 168-83; Brian Greene, *The Elegant Universe: Superstrings, Hidden Dimensions, and the Quest for the Ultimate Theory* (London: Cape 1999), c. 6, "Nothing but Music: Essentials of Superstring Theory," 135-65; Gerard 't Hooft (Nobel 1999), *In Search of the Ultimate Building Blocks* (Cambridge UK: Cambridge 2000), c. 28 "Dominance of the Rule of the Smallest," 175-80.

¹⁶ For a review of G. Veneziano (CERN) and his application of Euler's β -function (Euler integral) to the strong nuclear force (i.e., to strongly interacting particles), see Greene, loc. cit, 136-7, and Hooft, loc. cit., 85-90. Compare M. Ademollo, H. R. Rubinstein, G. Veneziano, and M. A. Virasoro, "Bootstrap of Meson Trajectories from Superconvergence," *Physical Review* 176 (1968): 1904-1925, and M. Ademollo, G. Veneziano, and S. Weinberg, "Quantization Conditions for Regge Intercepts and Hadron Masses," *Phys. Review Letters* 22 (1969): 83-5.

3. An Interpretation: Kant's Debut-Period in Euler's Mirror

This question—the Euler-Kant mirror—points to the two boundaries of Kant's debut, his first work, *Thoughts on the True Estimation of Living Forces*, and his Ph.D. thesis or “Habilitation”, *Joining Metaphysics and Geometry in Natural Philosophy*, sub-titled as the *Physical Monadology*. In 1744 or 1745, Kant started writing *Living Forces*.¹⁷ In 1756, he completed his education with *Physical Monadology*. Kant debut could accordingly be defined as the period from 1744 to 1756. Neither event, at either boundary, was really successful.

Whether there is indeed an “Euler-Kant mirror,” and if so, what it will mean, is a problem that has not yet been examined. The platform of such examination, and remainder of this paper, can only be an interpretation that is hopefully coherent and plausible at best. If this reading below makes useful inroads into the triad of scholarly puzzles mentioned above, it will have done its job. Here, the point is just a provocation—just a challenge to the dismissal of the precritical thoughts.

¹⁷ The chronology of *Living Forces* is as follows: probably in late 1744 and certainly during 1745, Kant began preparing and writing the manuscript. In spring or summer 1746, the work was done. In the summer semester 1746, Kant submitted the book to the academic censorship office. Also in 1746, he gave the sheets to the printer. By Easter 1747, he added a dedication, § 107-113a, and § 151-6. In August 1748, he left Königsberg, which delayed the publication. By August 1749, *Living Forces* appeared in print. See Kurd Lasswitz, “Anmerkungen,” Academy edition 1:521; also compare M. Kuehn (2001b), loc. cit., 94-5.

A very general cultural reflection will set the tone for the historical interpretation. Roughly speaking, we could say that Kantian modernity, like Habermas' work today, suggests the practical relevance of universally communicated truths about humans in the world. For the alternative to modernity—precritical philosophy of nature, like postmodern thought today—we could say that it involves studies of the action and fate of power (Foucault), of the interactive tapestry of voices (Plumwood), and of the relativism of context and significance (Lyotard, and pragmatically Rorty).

For the sake of the argument, both perspectives merit consideration. If this were true, a question would arise: how can early and late Kant be made to fit together—how can “living force contextually matters” and “rational truth” be made to resonate harmoniously? Scientific opinion praises the young Kant like Kant's older contemporary Euler. Kant-scholars, in light of Euler's *Tentamen Novae Theoriae Musicae* (1739), might wonder: is the natural tapestry of voices weaving sustainable patterns of natural organization and replicable rules of free action? If yes, what are the patterns?¹⁸ What is the “single general rule” of the cosmic flow to perfection, which the early Kant praises in *Universal Natural History* (II.7; 1:306.17-23) but never spells out?

Returning now to the interpretation, one could summarize the “success” of the two limiting events in Kant's debut-period as follows. *Living Forces* had hurt Kant's career prospects, and he was lucky to return to school in 1754. *Physical Monadology* worked to make him eligible for a professorial post, but he

¹⁸ In *Tentamen* Euler tried to make music part of mathematics and deduce interactive harmony from exact principles. The work failed; it was “for musicians too advanced in its mathematics, and for mathematicians too musical.” See J. J. O'Connor/E. F. Robertson (2004), loc. cit.

failed to get an offer. *Physical Monadology* served as thesis for his third defense (three were needed for an associate professor). His application for Knutzen's post led nowhere. Given the bad blood left between Kant and the late Knutzen, this was no surprise; Kant did not "fit" in this chair. Knutzen, in his own correspondence with Euler, had never included Kant on his lists of outstanding students.¹⁹

Moreover, by 1756, the year of the job search, the town knew the anonymous *Universal Natural History* was by Kant²⁰—and thus that Kant had been responsible for the irritating advice to Christians never to contradict natural laws to avoid embarrassing themselves (1:224.34-225.5). No job for this man! So he continued teaching as an adjunct and worked in the local library.

In Kant's debut-period, Euler's significance had grown continuously. There is no mention of Euler in *Living Forces*, nor is there any indication Kant knew the *Mechanica* (1736) by then.²¹ The last additions, in 1747, are on Musschenbroek, Châtelet, and Jean Bernoulli, not about Euler. In 1749, Kant wrote his homage, sent *Living Forces* to Euler, and stated his agreement with him. In 1754 he discusses "the brilliant Euler"

¹⁹ See Kuehn (2001a), loc. cit., 23, and Hans-Joachim Waschkies, *Physik und Physikotheologie des jungen Kant* (Amsterdam: Gruner 1987), 20n.

²⁰ See Johannes Rahts, "Anmerkungen zur *Allgemeinen Naturgeschichte*," *Academy* 1:545. A year after publication (March 1755) of *Universal Natural History*, a note appears in the classified ads of the local weekly, *Wöchentliche Frag- und Anzeigungs-Nachrichten* (1 May 1756): "Book printer Driest sells: Magister Kant's *Universal Natural History and Theory of the Sky*."

²¹ For the index of persons, sans Euler, see Juan A. Canedo-Aguelles, "Comentario," in Kant, *Pensamientos sobre la verdadera estimación de las fuerzas vivas* (Bern: Lang 1988), 189.

(*clarissimo Eulero*, 1:378.2-3) in his M.A. thesis on *Fire*. At issue is the “matter of light” (*materia lucis*), the structure of fire. How is fire or light structured? Newton says in *Opticks* (1704) that it is particles; Euler defends in *Nova Theoria Lucis et Calorum* (1746) Huygens’s idea that it is waves. Kant, apparently applying Bilfinger’s Chinese dialectics, suggests a synthesis: fire has both particle- and wavelike properties. Kant’s “fire-matter” (*materia ignis*) binds particles and vibrates the bound matrix as waves that are called heat (prop. 7; 1:376).

There is no mention of Euler in *Physical Monadology* either. Instead, the dissertation is the defense of a solution to a problem that Euler considered unsolvable. It concerns the structure of matter. Euler had argued in *Thoughts on the Elements of Bodies* (1746) that matter must be infinitely divisible because it fills an infinitely divisible volume. So there cannot be any ultimate elements, be this material atoms or energetic monads. Euler’s view became a popular opinion; by mid-century, monads were frowned on. In 1747, monads had been officially rejected by the Prussian Academy of Sciences—under the leadership of Maupertuis and his deputy Euler.²²

Kant’s solution of Euler’s problem in *Physical Monadology* is a defense of monads. This was probably an ill-advised move. *Living Forces* had ruined Kant’s relationship

²² Maupertuis became president of the Berlin Academy in 1744. One of his duties was to select a topic for a biannual prize question. He announced an essay contest on Leibniz’s *Monadology* (1714) in 1745. The finalists were a pro-monad paper (Stiebritz) and an anti-monad paper (Justi). The vote by the philosophy division was a tie. Maupertuis refused to split the prize. Euler—his deputy and director of the math division—pressed for a vote of the entire academy. Members of the math and science divisions were mostly Newtonians critical of Leibniz. The anti-monad paper won the general vote, and Justi got the prize in 1747. See Schönfeld, loc. cit., 161-3 and 283-4.

with his teacher; *Universal Natural History* had undermined his reputation in Königsberg; and *Physical Monadology* was now discrediting him in Berlin, where decisions for professorial appointments were made. The Royal Prussian Academy of Sciences was ruled by Newtonians and in the majority French. Leibniz had fallen out of favor. From the sophisticated perspective of the Berlin Academy, Kant must have seemed like a townie in the countryside, ten years out of step with the times.

And yet, Kant's solution is in light of current science oddly correct. His physical monads can be argued as conceptual mirrors of mathematical superstrings. There is some irony that Euler dismissed monads but found the β -function, a tool whose physical use led to superstrings—which resemble the very monads he dismissed. But at the same time, this irony is not too rich, since it is unfair to Euler. Euler dismissed Leibnizian monads; Kant argues for something else. Kant's monads of *Physical Monadology* originate in the active substances of *Living Forces*, and these substances integrate some aspects of Leibniz's monadology while excluding others traits. Kant's "physical monadology" is a quite drastically revised version of Leibniz's former hypothesis.

Physical Monadology proceeds from the dynamic foundation laid in *Living Forces*. The first ten sections of *Living Forces* are a metaphysical essay. The first section is probably Kant's earliest known statement. He writes that the "whole lot of scholastics prior to Leibniz" had failed to understand Aristotle's "dark entelechy." It was Leibniz, who was the first to teach that bodies have essential forces—a force so fundamental that it is prior to extension itself (1:16.14-24).

Leibniz's claim, which Kant finds so important that he states it twice in *Living Forces*, is that force comes first and even precedes extension (§ 1; 1:17.21-4). Examples of extension

are matter and space (matter has volume, and space is volume). Since force is prior to extension, matter and space are not primitives. Before they emerged, nature began with force.

For Kant, concurring with Leibniz, nature's rock bottom should be called an "active" force. He rejects Wolff's opinion that force is responsible only for physical movement (§ 2; 1:18.2-16). Kant sticks to Leibniz's radical idea that force is responsible for motion and action in general.²³ Forces are so basic that motion is not even a necessary condition of force, for motion, like rest, is a state, and it is changes of state, not states as such, that depend on applications of force. So some bodies exert force at rest, while others fail to exert force when moving (§ 3; 1:18.22-36).

Now Kant breaks with Leibniz (§ 4). He rejects pre-established harmony. Leibniz had assumed that interaction is just an emergent property without being part of the set-up of nature. But Kant takes interaction as a mark of substances and suggests, when substantial forces act, they do so by affecting

²³ In *Living Forces* § 2-3, Kant rejects Wolff's *vis motrix* as a label for general force. The issue is how to call force—what is its "general name" (1:18.2-3), its "nearer determination" (1:28.5-6), or how to "talk ... correctly" (1:18.18). *Vis motrix* is rejected as a basic label, not as a specific type. For Kant, Wolff's mechanically "moving force" à la Keill is compatible with a basic "active force", just as a specific kinematics is compatible with a general dynamics. Cosmology illustrates this. In *Universal Natural History*, force (the dynamic basis) governs action universally-interactively, while attractive and repulsive motions (the mechanical kinematics) are what specifically pumps out order and diversity, cf. preface (1:234.27-31) and chapter II.7 (1:306-331). Hence Kant's acceptance of *vis motrix* in *Physical Monadology*—as "that the inner force of elements must be a moving one, as one applied externally ... and that strives to either repel or attract"—does not constitute a contradiction to the earlier semantic rejection, cf. preface (1:476.7-9).

others.²⁴ Kant's monads have windows. They interact. In his PhD. thesis *New Elucidation of the First Principles of Metaphysical Cognition* (1755), he calls his own theory the "interactivity by truly efficient causes" (*commercium per causas vere efficientes*; 1:415.33).

Dynamic action is central to Kant's earliest ontology and essential to physical monads. The logic of claims in *Living Forces* so far—that there is force, that it acts, that it acts outwardly, and that it affects others—seems like a string of non-sequiturs. But in fact, there are conceptual connections from present force to outward action, and next from outward action to foreign effects. The logic of Kant's account is actually valid; there is no semantic flaw, only a linguistic difficulty.

In this account, force is the primal presence; it would not be so if it did not act (*wirken*). Force "happens" by leaving marks, by having effects (*Wirkung*), for an ineffectual power is not a power. But for any power, its effect or action—Kant's *Wirkung* means both, a *wielding*—must be outbound to be real. A power failing to leave marks (a power sans wielding) would be an event without any trace. Sealed off from its environment, it would not exist for this environment.

Thus force, by default, is presence through outbound action and environmental reactions. Such activity, by definition, would affect something other than its source. For Kant, quite correctly, force radiates by "stretching" or "broadening" itself

²⁴ "Nothing is easier, however, than to derive the origin of what we call motion from the general concepts of active force. Substance A, whose force is determined to act externally (that is, to change the internal state of other substances), either immediately encounters an object that receives its entire force at the first moment of its endeavor, or it does not encounter such an object." See *Living Forces* § 4; 1:19.2-6.

out. When dynamis is “in action” (en-ergon), it is accordingly energetic, wielding effects.²⁵

Force extends space by producing order, connection, and structure.²⁶ How, exactly, this happens—how force makes space and then interacts with it—is at issue in § 10 of *Living Forces*, the climax of the metaphysical essay. Here I only want to focus on the general behavior of force that Kant suggests, now part of the standard picture in physics. He writes that force spreads its effects outwardly (§ 10; 1:24.23; *ihre Wirkungen von sich ausbreiten*—if one “Germanizes” the text, it will read: force broadens its wielding out from itself). A presence acts outwardly, on an emptiness that surrounds it. Its action is the out-broadening of the presence into the emptiness, thereby filling and shaping it. When force spreads out, it radiates as a field. The field expands as a volume and extends as a space. Therefore force turns void into space, the order of radiation.

As soon as an extended field exists, the acting force is present *inside* its expansion. The created environment of force gives it context and is the frame in which force acquires its

²⁵ See § 9: “It is easy to show that there would be no space and no extension (*Ausdehnung*), if substances had no force to act external to themselves (*ausser sich zu wirken*); for without this force, there would be no connection; without connection, there would be no order; and without order, there would not even be space.” (1:23.5-9). To see this, assume a power emerges, prior to anything else, as an unspecified presence. As long as it has not been modified, it will lack structure—it begins as an unmitigated force, which acts by just spreading itself. Kant’s words are *ausbreiten* (1:24.23, “out-broaden,” radiate) and *Ausdehnung* (1:24.6; “out-stretching,” extension).

²⁶ See § 7-9: As Kant argues, whatever exists in our world is connected with anything else (§ 8; 1:22.27-23.3). Connections are constitutive of a frame. Positions presuppose a frame and hence relations; without connections weaving nature, there would be no location within it (§ 7; 1:22.3-13). Nature’s nexus is due to outbound actions of force, which generates place (§ 9; 1:23.5-9)—the spatial anchor of dynamic interconnection.

location. The field, as the spatial action of force, localizes the dynamic source—force is now placed. The placing of force within the field curdles the presence into parts. It acquires structure: there is an acting point source and its sphere of radiating activity. Structures always order currents (think of riverbeds or wings!). The spatial field is no exception. As force orders space, space now governs force. Space shapes the source to a point and governs the rate of the flow from the well.²⁷

Kant's earliest dynamics presents a conjectural account of the standard picture today. For Kant, force orders space, and space orders force. Without force, space would lack structure (*Abmessungen* or *Dimensionen*) and could not place a world (§ 9). Without space, force would lack a field, and its radiation would not have a rate (§ 10). That is, for Kant, as soon as force creates space, force and space will interact—when space is forced out, force is placed inside. This interaction of force and space is fundamental, and with this insight, Kant anticipates a central idea of general relativity, that mass stretches spacetime and that spacetime grips mass.

As Kant's discovery of force-space interaction grounds his later physical monadology, the matter-theory of *Physical Monadology* is both an extension and an application of this discovery. Kant's monads are interactive force-space units. His departure from Leibniz reveals the traits that these "new and improved" monads share with superstrings. Consider how they are the same. Kantian monads and superstrings are matter's final units (*partes primitives*; prop. 2, 1:477.16). Both make matter

²⁷ Kant next states in § 10 the generalization of Kepler's law of photo measurement (1604). Kant's law of free field radiation is now recognized as a general pattern of various radiations; see Cambridge Edition *Natural Science*, "Factual Notes," in press.

without being matter (§ 1, 1:16.20-3; prop. 6, 1:480.36-9). As matter's units, monads and superstrings are energetic (prop. 8-10, 1:482-4). They are potentials enacted; that is, potential powers that act out as radiations. Their radiation yields extended fields (*monas ... spatium implet*; prop. 7, 1:481.35-6). Fields are the environments of the ultimate force-centers (*ambitus externae praesentiae huius elementi*; prop. 7, 1:481.26); force-centers radiate volume (ibid, 1:481.9-39). Their radiation whips out dimensional structures that place the centers (ibid.). So they make space by being inside their spaces. Thus, energetic bubbles (*sphaera activitatis*) are the basic constituents of matter (prop. 6, 1:480.36-9). These monadic "activity spheres" lack further parts (prop. 1, 1:477.5-7), but they are *not* infinitely small either (prop. 4, 1:479.14-15).

For Kant, Euler's (*permultis physicorum*) standard conception of space is perfectly right, not just geometrically but also in nature. Euler's problematic divisibility of space applies to the issue of material elements, and for Kant, appealing to differences of formal and natural spaces would just be a cheap evasion, not a real solution (cf. prop. 3, 1:478.35-479.1). For Kant, geometry nails it. Euler is definitely right. But metaphysics nails it too, Kant thinks. Now he can push the envelope: joining geometry and metaphysics over space solves the problem of matter. Basically, the final units of matter are analyzable *dynamically* without being divisible *structurally*. That is to say, whenever we point at one part of the element we are bound to look at another. There is "center" and "volume" to both superstrings and Kant's physical monads, and although "center" and "volume" are logically distinct they factually prohibit divorce. The elementary units, as centers, are pulsing points ordering their context. The pulse of the points has a dual rhythm; it is a binary radiation of attraction and repulsion. Repulsion is locally strong and falls off quickly. Attraction is locally weak but reaches far. Off-center, some distance a-Way,

radiation is balanced, and attraction levels repulsion. For the power point, this is the sustainably happening boundary of its “activity sphere.” Superstring theory calls Kant’s activity spheres “Calabi-Yau spaces” today.

The beauty of Kant’s physical monads, of his metaphysical superstring-conjecture, is how power point and activity sphere prohibit divorce. Their natural fit is so right that a cynical analyst trying to split up their marriage with logical wedgies will only reveal ignorance of how things work. For it is perfectly intelligible how power point and activity sphere are unthinkable without the other. Centers inflate volumes—just as volumes are centralized inflations. Without volume no center, and without center no volume. The metaphysical cognition of the ultimate elements reveals their dynamic interactivity of structural aspects, whose joint identity is essentially binary. Thus, Kant states in his ontology (plausibly, as seen from the viewpoint of science now) that identity as such, taken as the absolutely first principle, is a binary truth (*New Elucidation*,

prop. 2; 1:389.3-6).²⁸ And perhaps the same binary truth applies to the link of metaphysics to geometry, of Kant to Euler, who both need the other in order to make jointly better sense of nature. If this reading of Kant's debut-period is defensible—if the Euler-mirror does not break when examined—then it will point to the integration of the precritical and critical Kant into one powerful heuristic perspective. The philosophical implications, I fancy, could be striking.

²⁸ See Kant, "New Elucidation," *Theoretical Writings 1755-1770*, Cambridge, 6-7: "Proposition 1: There is no *unique*, absolutely first, universal principle of all truths... Proposition 2: There are two absolutely first principles of all truths. One of them is the principle of affirmative truths, namely the proposition, whatever is, is; the other is the principle of negative truths, namely the proposition: whatever is not; is not. These two principles taken together are commonly called the principle of identity." (Trans. D. Walford and R. Meerbote). For the German idea of binary identity, see G. W. Leibniz, "Explication de l'arithmétique binaire qui se sert des seuls caractères 0 + 1, avec des remarques sur son utilité, et sur ce qu'elle donne le sens des anciennes figures Chinoises de Fohy [I-Ching]," *Mémoires de l'Académie Royale des Sciences de Paris* 1703, in *Mathematische Schriften*, ed. Gerhardt (Berlin/Halle 1848-63, Hildesheim: Olms 1971), 7:223-27. Also see Leibniz's *Annotationes de cultu religioneque Sinensium* (1708; attached to a note to Des Bosses 12 Aug 1709) in *Philosophische Schriften*, ed. Gerhardt (1879, Hildesheim: Olms 1978), 2:379-84; as well as in *Discours sur la Théologie Naturelle des Chinois*, ed. W. Li and H. Poser (Frankfurt: Klostermann 2002), 265-70. (The 2002- edition of *Annotationes* has excellent notes.) Leibniz writes (1978:383 and 2002:268): "Fohium antiquissimum Sinensium principem et philosophum agnovisse originem rerum ex Unitate et Nihilo, id est aliquid Creationi Analogum, ostendunt arcanæ ejus Figuræ, Arithmeticam dyadicam, à me post tot annorum millia restitutam continentes, quanquam et majora innuentes, ubi omnes numeri scribuntur per binas tantum notas 0 et 1."

